SSD Survey Update

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3/21/2013

The SSD

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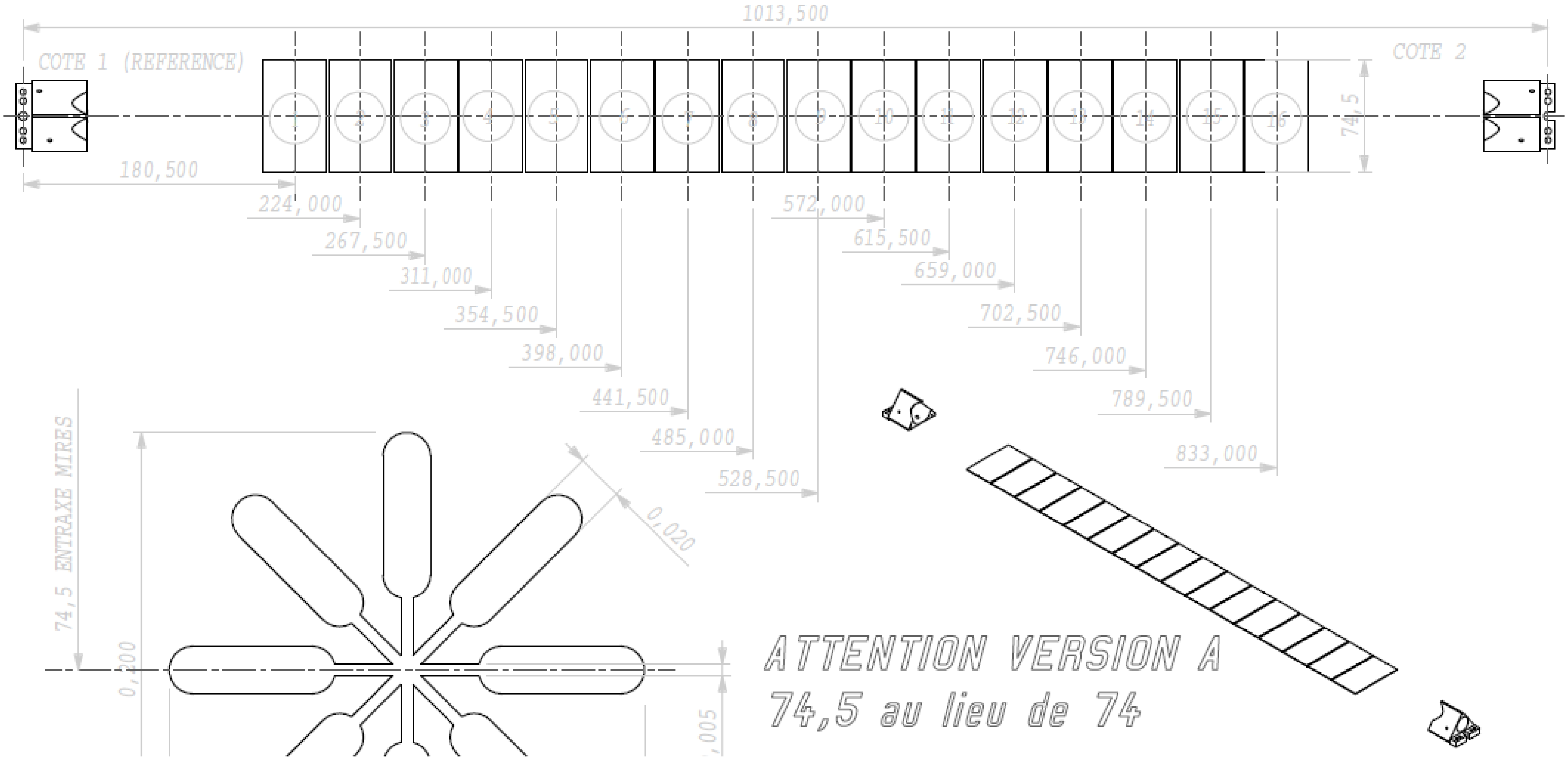
- **Who:**
  - Bob Connors is the expert. Joe Silber and Hans Georg have done Yeoman work.
- **What:**
  - Multiple targets on each Si module, measure relative to pin on end
  - Mounts on OSC need to be surveyed at LBL
- **When:**
  - Winter & Spring 2013
- **Where:**
  - LBL shops
- **Why:**
  - Survey will give position of silicon sensor with respect to the mount points on the OSC
- **How:**
  - Optical survey machine at LBL (already exists)
- **Schedule:**
  - Expected to be able to survey 2 ladders per day, so approximately two weeks to do all 20 ladders … currently about 1 per week ☹

The Theoretical Geometry Model



- **Two "single" star targets, one on each end**
  - **visible on front and back**
- **Fourteen "double star" targets, seven on each side**
  - **visible only from the front side**

What do we know?

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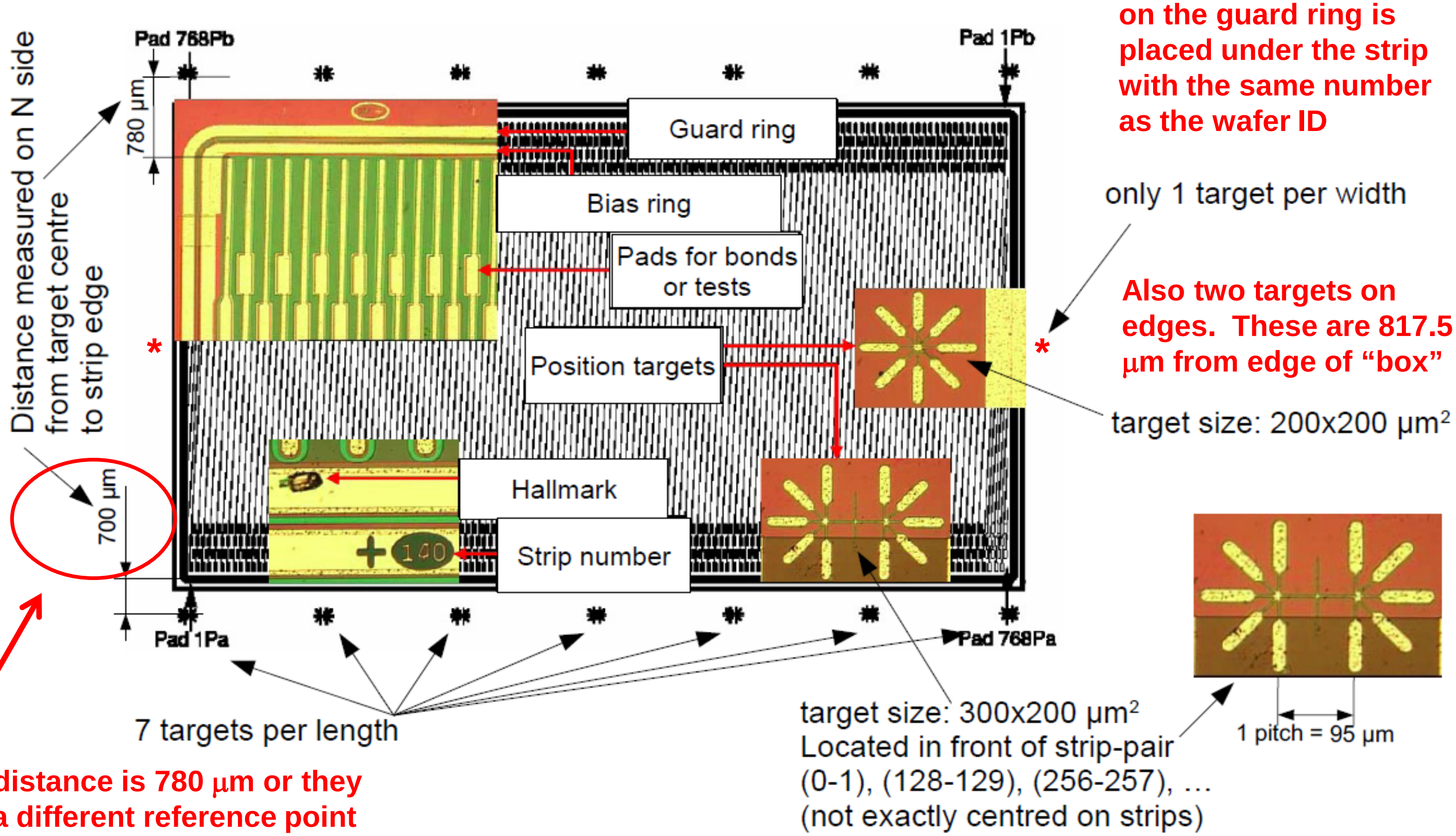
STAR-SSD sensor geometrical specification,
according to documents used to order the sensors and measurements.

J.Baudot 2012/04/02, updated 2012/04/20 **Updates by Jim Thomas, based on LBL Survey 3/30/2013**



The hallmark (or punch) on the guard ring is placed under the strip with the same number as the wafer ID

Also two targets on edges. These are 817.5 µm from edge of "box"

Target distance is 780 µm or they meant a different reference point

Detail on Module structure

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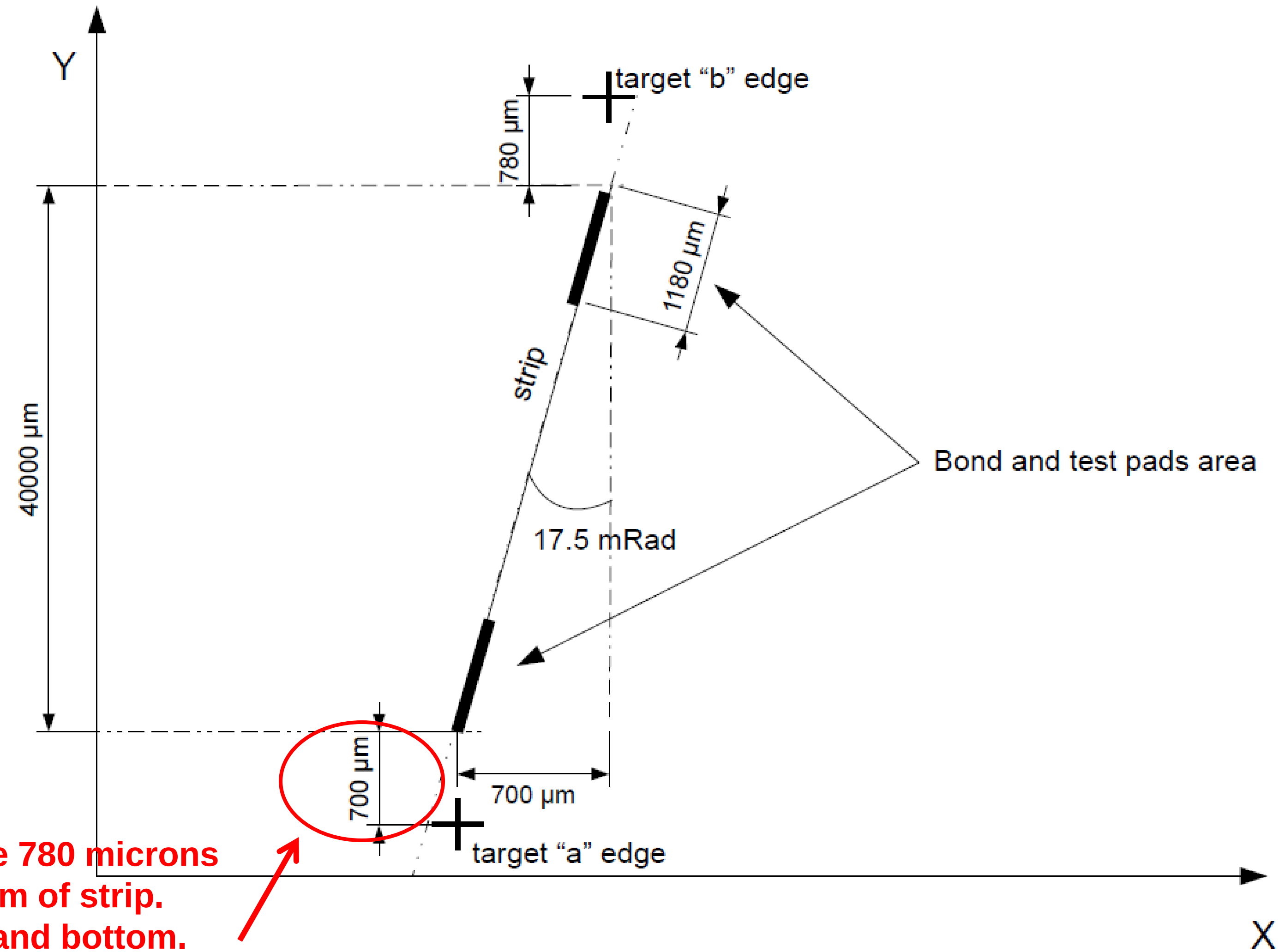

Targets are 780 microns from bottom of strip. Same top and bottom.

Coordinate system parallel to the detector edges

Geometry – Assume “A” edge toward pin

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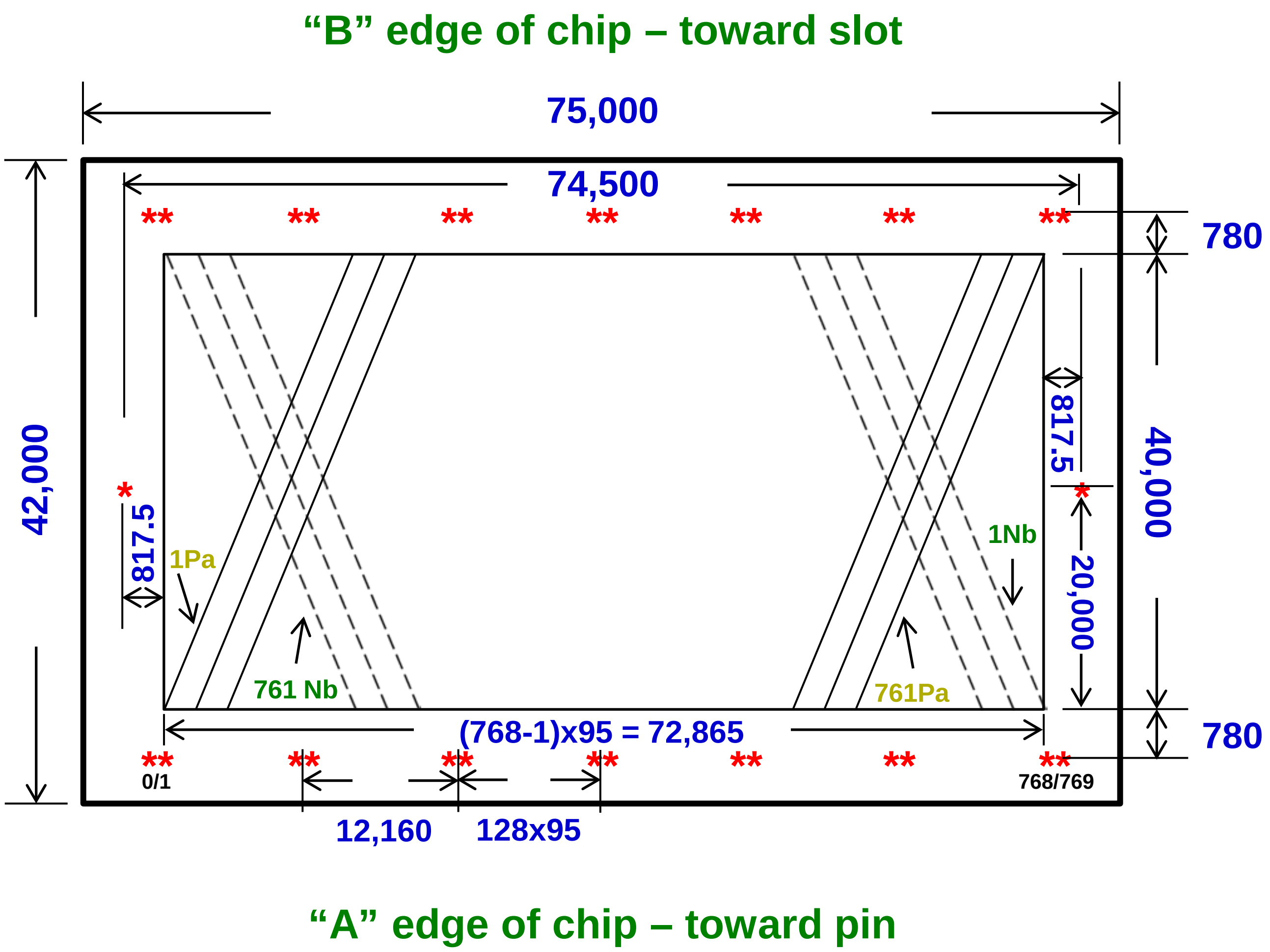

The inner box is imaginary. It defines the area covered by 768 stripes.

Inner box is wide enough for 768 stripes, edge to edge, with 95 μm pitch.

Thus the box is (768-1)*95 = 72,865 μm wide and 40,000 μm tall.

Double star targets are centered on the middle of the wafer and spaced 128 μm apart. STAR 1 is under strip 1, etc. Note that first star is for strip 0, which doesn’t exist.

Pin side of ladder is labeled “P” side
Pa and Pb stripes are face up for survey, Na and Nb are on the backside, normally not visible.

Not to Scale

Calculating the Coordinates of a hit

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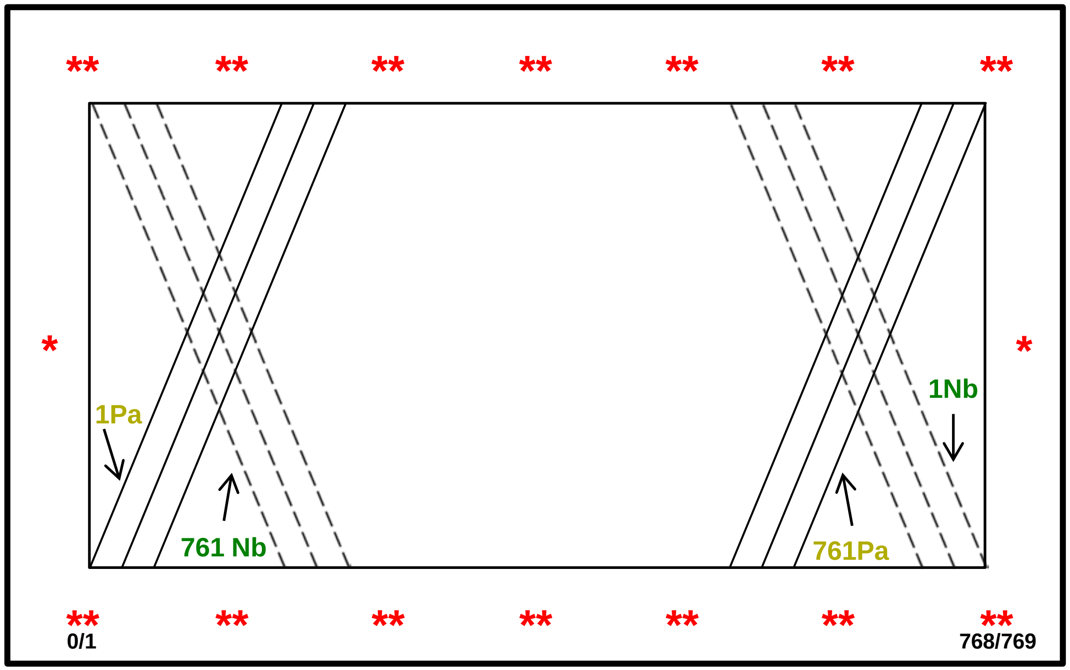
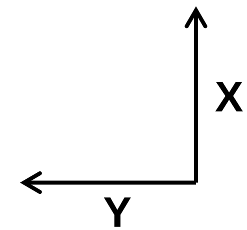
Assume straight lines of the form: $y = mx + b$

For 1 hit, we must assume $x = 0$ and then:

$y = 36082.5 - (\text{NumberPa}-1)*95$ or $y = -36082.5 + (\text{NumberNb}-1)*95$



Not to Scale



X starts at the pin and points to the slot. Z is "up" as seen by the surveyor. See photo.

Assume (0,0) at the center of the wafer for this work.

Pa Stripes: Slope = -0.0175, Intercept = $36082.5 - (\text{NumberPa}-1)*95$

Pa Stripes: Slope = -0.0175, Intercept = $(768-1)*95/2 - 0.0175*20000 - (\text{NumberPa}-1)*95$

Nb Stripes: Slope = 0.0175, Intercept = $-36082.5 + (\text{NumberNb}-1)*95$

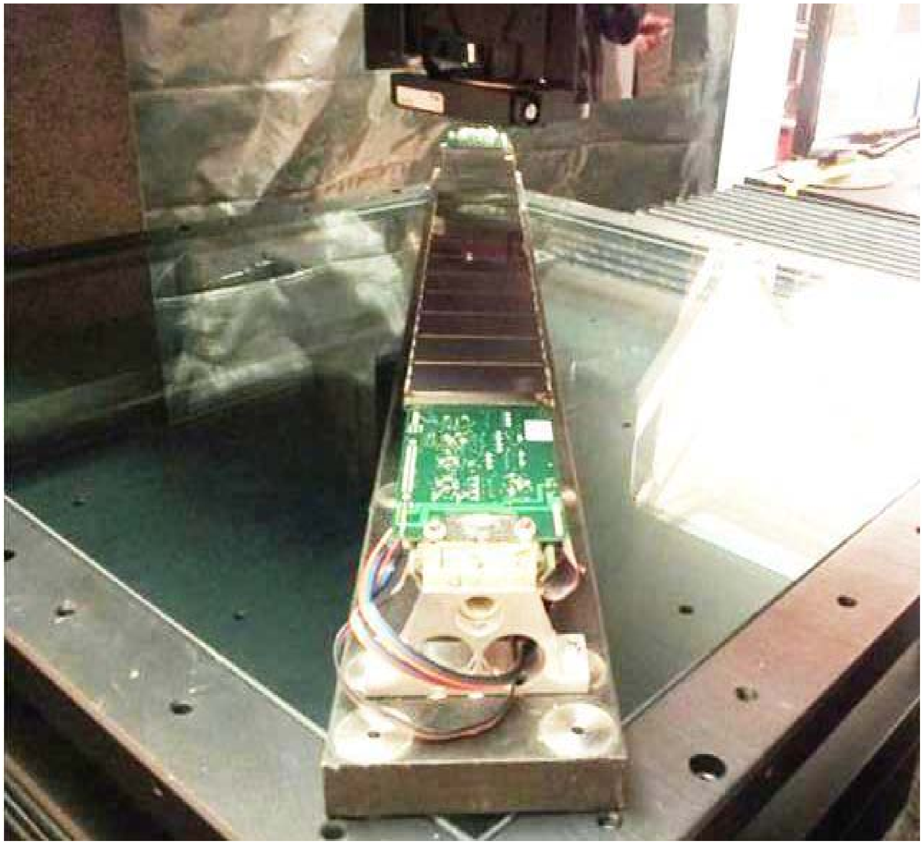
Nb Stripes: Slope = 0.0175, Intercept = $-1*(768-1)*95/2 + 0.0175*20000 + (\text{NumberNb}-1)*95$

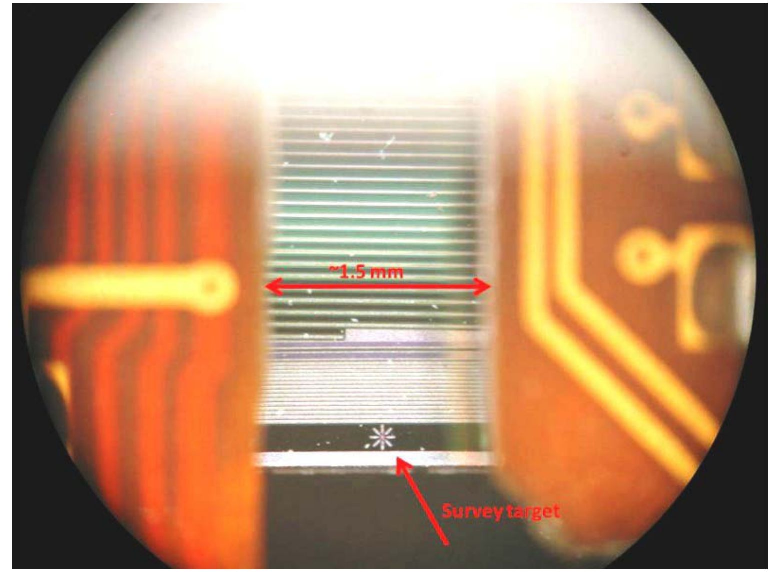
With 2 hits, one on each side of the wafer, then:

$x = (b(\text{Nb})-b(\text{Pa})) / 2*m(\text{Pa})$ and $y = (b(\text{Nb}) + b(\text{Pa})) / 2$

$x = (768 - (\text{NumberNb} + \text{NumberPa}) + 1) * 95 / (2*0.0175) - 20{,}000$ and $y = (\text{NumberNb} - \text{NumberPa}) * 95/2$

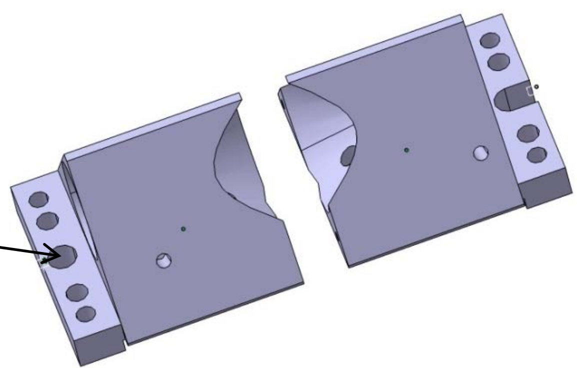
Pictures

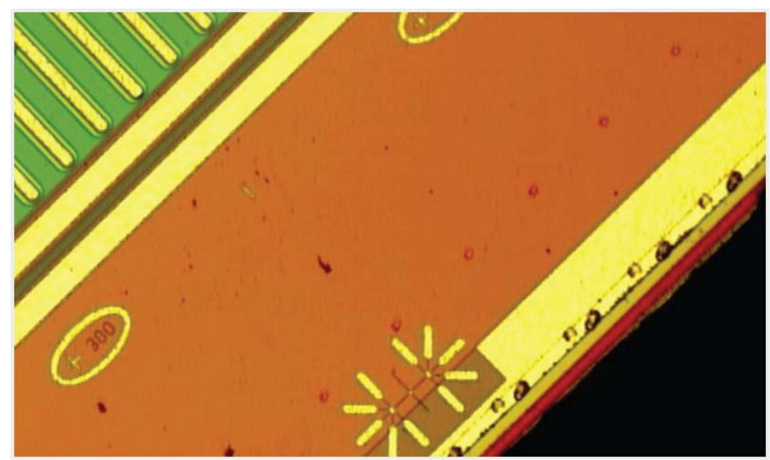




Target on end of wafer (backside)

Reference point





Targets on edges of wafer (front)

To do (written 1 year ago … but still true)

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Philosophy: start from the module and work outwards

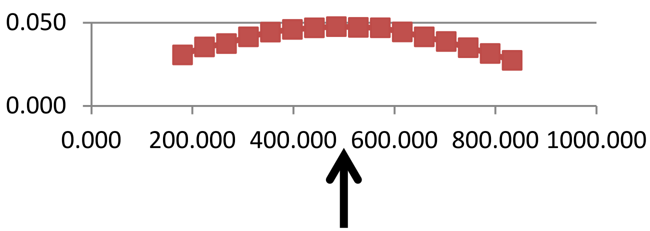
- Measure location of strips relative to targets (one wafer)
- Measure location of targets on wafers relative to pin (all)
- Repeat for all ladders
- Check gravity sag on one ladder (this can be done on Zeiss)
  - Assume that 0° and 90° are sufficient to characterize sag
  - Repeat 90° measurement on all ladders if necessary
- Record and manage data
- Design, glue, and survey location of mounts on OSC
- Develop mathematical transforms from strip to target to pin to OSC mount to STAR Global Coordinate system
- Record and store in STAR qualified DB

Results

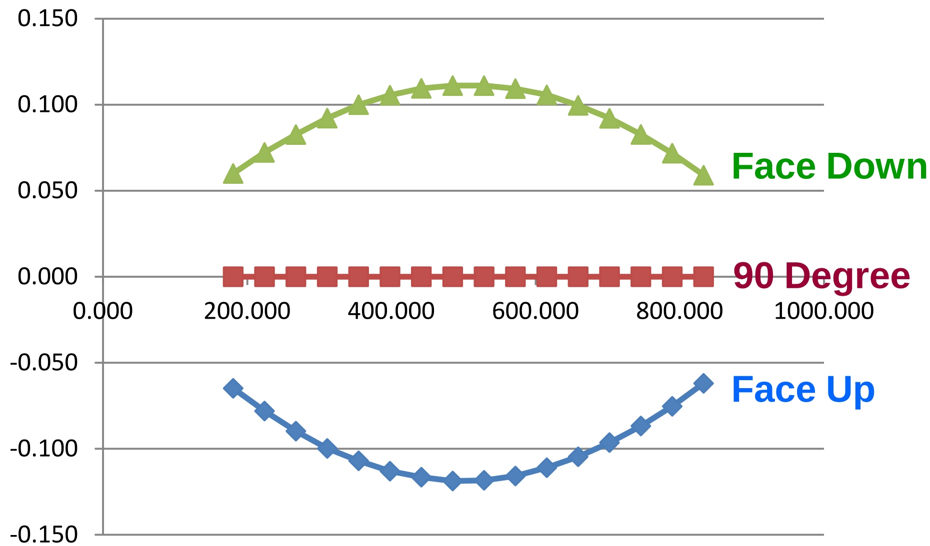
dX0	-0.336
dY0	0.359
dZ0	-0.072
Rot(Rad)	-0.008
ResX	0.009
ResY	0.008
ResZ	0.079

dX0	0.028
dY0	-0.001
dZ0	-0.158
Rot(Rad)	0.000
ResX	0.005
ResY	0.007
ResZ	0.179

- **We have surveyed 3 ladders**
- **We know the mean displacement of each wafer from its ideal location and rotation angle wrt ideal**
  - **Typically, the first wafer is far from the ideal location**
  - **Other wafers are usually very close (10 or 20 μm)**
- **Z location of the center of each wafer is strongly dependent on location on ladder due to gravity sag**



Bend in the "strong" direction at 90 Degrees



Folded Wafers

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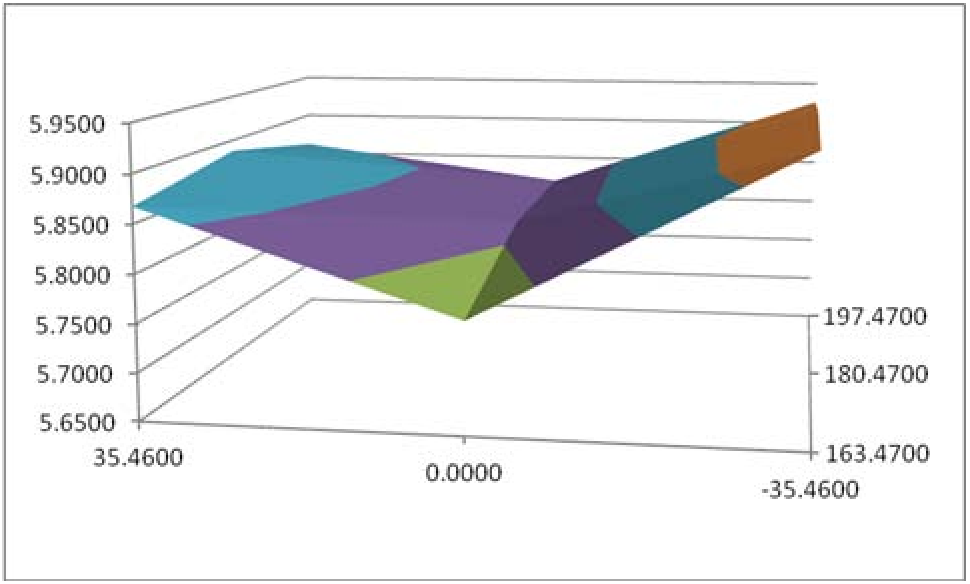
- **Curiously, most of the wafers are also "bent" in the middle**
  - 9 point survey so the bend is probably a smooth curve
  - Perhaps due to gravity sag during gluing on the ladder?



Summary

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- Data looks good
  - Reproducible
  - Accurate to at least 20 μm … probably better
  - Survey procedures seems robust and reliable
  - Data formats are well defined and easy to use
- We have located two the errors in documentation
  - Targets top and bottom of "box" are 780 μm off the box
  - Targets left and right are 817.5 μm off the edges of the box
- Wafers are not in the theoretically designed position
  - X,Y misalignments up to 0.5 mm (usually first/last wafer on ladder)
  - Wafers are bent or folded.
    - Of order 200 μm
    - Is this important?
  - Z displaced from neutral position by gravity 50 to 150 μm
    - Is this important?
    - If so, will have to calculate the sag for each orientation on OSC

Backup Slides

Software proposal

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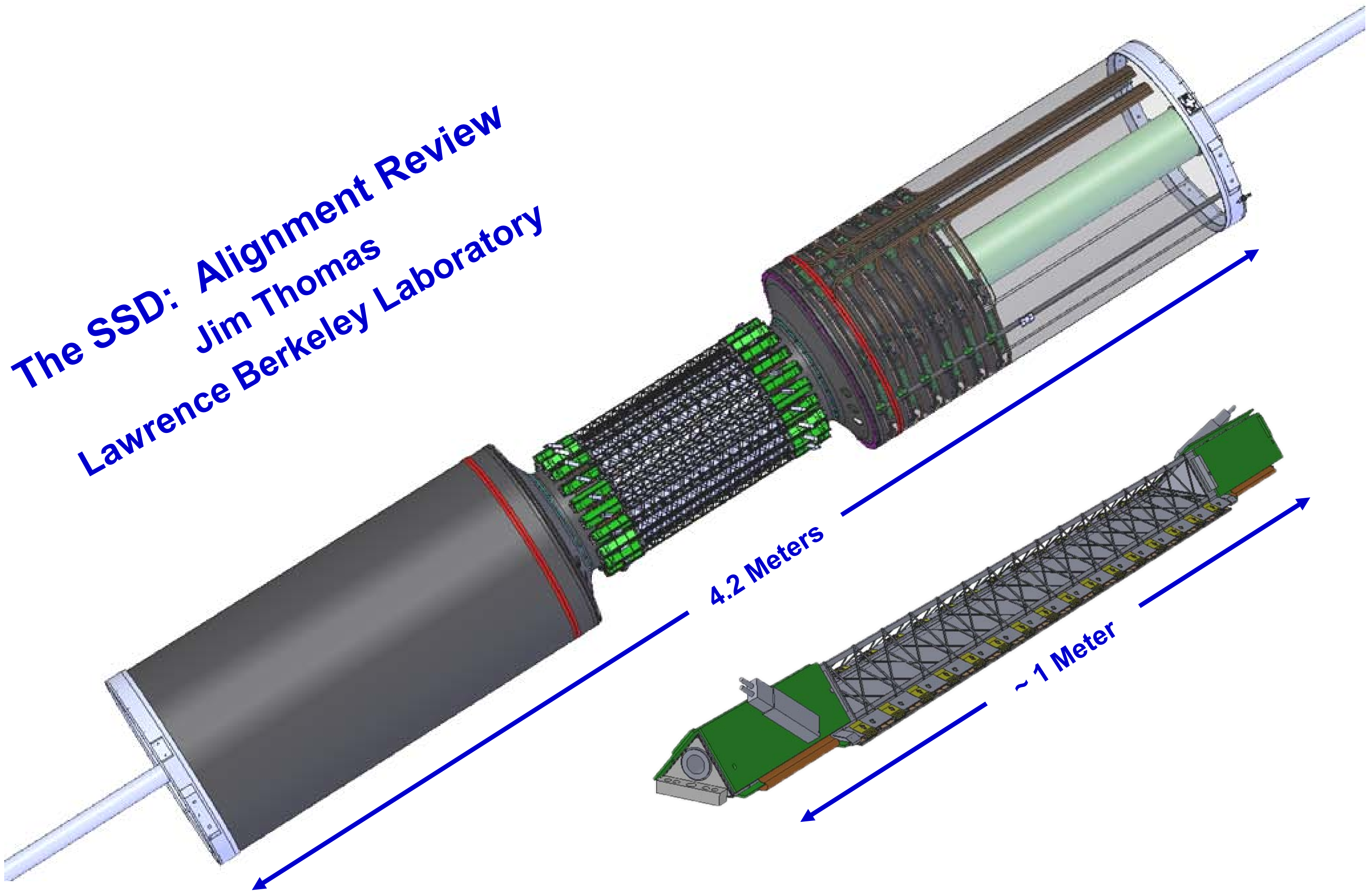
```
void GetHit( Int_t &nPa, Int_t &nNb, Int_t &Wafer, Int_t &Ladder )
{
 // Get and return nPa, nNb, Wafer number and Ladder number
 // nPa is the strip number on the P side, nNb is the strip number on the N side
}

void  xyzLadder( Float_t xWafer, Float_t yWafer, Int_t Wafer, Int_t Ladder, Float_t
        xLadder[] )
{
 // Convert from local wafer coordinates to ladder coordinates
 // Compensate for rotation and bend of wafers but do not correct for gravity or phi
        (yet)
}

void  xyzOSC( Float_t xLadder[], Int_t Wafer, Int_t Ladder, Float_t xOSC[] )
{
 // Convert from Ladder coordinates to OSC coordinates
 // Compensate gravity and phi location effects on OSC
}

void xyzSTAR( Float_t xOSC[], Float x[] )
{
 // Convert from OSC reference frame to STAR reference frame
}
```

```
Int_t   xyWafer( Int_t nPa, Int_t nPb, Float_t &xWafer, Float_t &yWafer )
{
 // Convert hits on strips to local X,Y coordinates on the wafer
 // Wafer has 768 strips on each side of the wafer (starting from 1)
 Float_t Slope = 0.0175  ;  // Slope of the strips on the wafer (Radians)
 Float_t Pitch = 95.0    ;  // Distance between strips along the Y axis (microns)
 Float_t Width = 40000.0 ;  // Width of active region on wafer along X axis (microns)

 if ( nPa == 0 || nPa > 768 ) && (nNb == 0 || nNb > 768 )
   return 0 ;
 if ( nNb == 0 || nNb > 768 )
   {
     xWafer  =  0.0  ;
     yWafer  =  (768-1)*Pitch/2.0 - Slope*Width/2.0 - (nPa-1)*Pitch ;
   }
 else if ( nPa == 0 || nPa > 768 )
   {
     xWafer  =  0.0  ;
     yWafer  =  (768-1)*Pitch/2.0 - Slope*Width/2.0 - (nNb-1)*Pitch ;
     yWafer *=  -1.0 ;
   }
 else
   {
     xWafer  =  (768 - (nNb + nPa) + 1) * Pitch / (2.0*Slope)  -  Width/2.0  ;
     yWafer  =  (nNb - nPa) * Pitch/2.0 ;
   }
 return 1 ;
}
```

The SSD



The SSD: Alignment Review
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4.2 Meters
~ 1 Meter

The Lorentz Force affects the SSD

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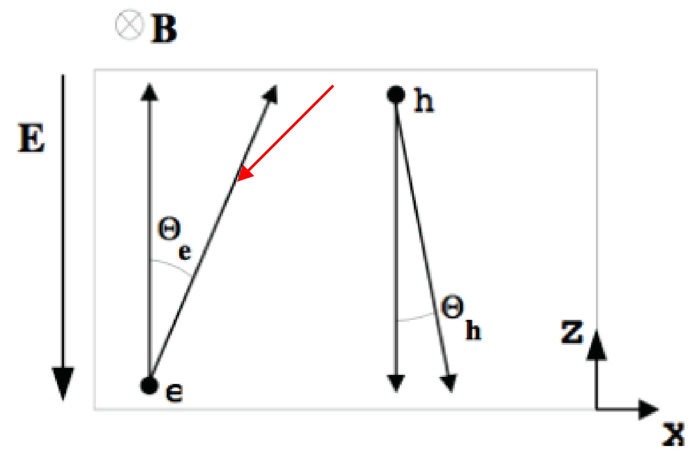
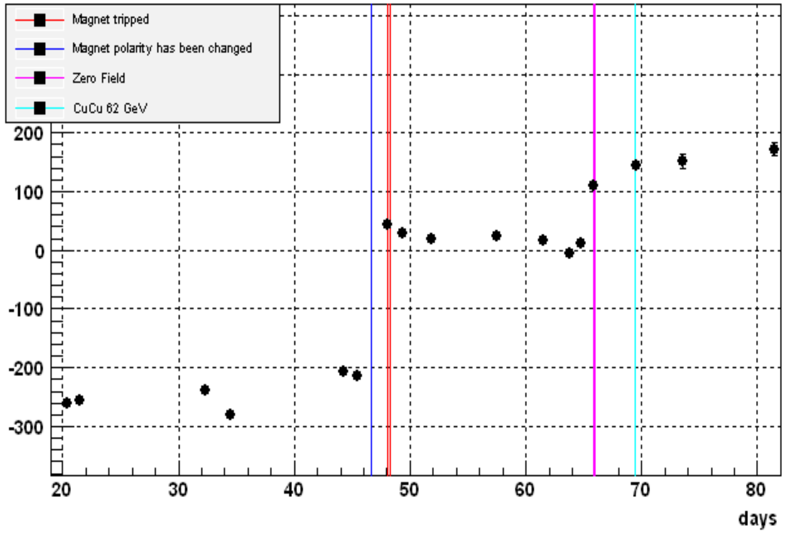
- **Lorentz effect :**
  - Trajectory of electrons/holes are modified due to the combination of the STAR magnet B-field and the SSD wafer E-field (vxB)



- **Observation from data :**
  - Shift in <z> direction of the order of 200 μm depending on the B-field orientation.
  - Oops. Not all shifts explained by sign and Mag of B. (?)



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Lorentz Effect Corrections … already in code

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- **Values from CMS**
  - θ_L = 21° for electrons and θ_L = 8° for holes
  - T =280 K and V_{bias} = 40 V *http://arxiv.org/pdf/physics/0204078v2.pdf*
- **Normalized to STAR B-Field**

$$tan(\theta_L^{STAR}) = \arctan(\tan(\theta_L^{CMS}) \times \frac{B^{STAR}}{B^{CMS}})$$

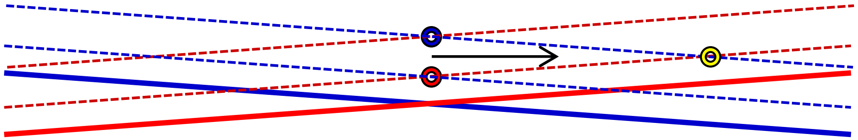
→ θ_e = 4.4 °, θ_h = 1.6 °

$$\Delta(x) = \tan(\theta_L^{STAR}) \times d$$

→ Δx = 12 μm for electrons, Δx = 4.2 μm for holes

d = drift distance along the E-field (d =150 microns , half-thickness of the wafer)

Thus the anode and cathode strips will experience different distortions on the two sides of the detector. When reconstructed, this leads to a distortion in the Z direction approximately equal to $\tan(\theta_e - \theta_h)$*d / $\tan(\theta_{ac})$ or about 210 μm.



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